VOLUME XXXV NUMBER 7 WHOLE NUMBER 306

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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PUBLISHED MONTHLY
(Ten numbers per year)

September, 1941

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

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Covers, extra, 50 copies, $1.50; 100 copies, $2.00; 200 copies, $2.50.

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PRINTED IN CANADA

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THE ROLE OF MATHEMATICS IN ASTRONOMY*

By ALFRED T. DELURY

THE guardian angel of the Committee on Programmes—Mr. Collins,—in urging me to speak at one of the meetings in Toronto, suggested treating in a simple way the part played by mathematics, in the severer sense, at certain high moments in the development of astronomy, and offered as a title, "The Rôle of Mathematics in Astronomy". After the meeting it was suggested that the address be written up for the JOURNAL: this I now reluctantly do.

Astronomy as a science may, for us, be said to have originated with the Greeks, though as is well known, to the Greeks it had a distinguished past, mainly in a statistical sense. Much the same may be said of mathematics, which, developed by them for its own sake, for its intrinsic beauty, was enlisted in the service of astronomy, and there was constructed the scheme of the universe which came to be known as the Ptolemaic system. Uniform motion in a circle was the fundamental assumption and apparent irregularities were explained by epicycles; for example the peculiar motion of the planet Venus was explained by the motion of an empty centre moving uniformly about the earth, the actual planet moving uniformly in a smaller circle about this moving empty centre. Additional observed irregularities were explained by additional epicycles. Ptolemy's great work brought all this together, and the geocentric system remained practically static for centuries.

The Greek interest in mathematics had soon passed beyond the

*Address to the Royal Astronomical Society of Canada, Toronto Centre, March 18, 1941.

elementary geometry whose concern was the plane, the straight line and the circle. More complex curves than the circle were discovered, invented or defined, notably—and near to the circle—the conic sections, the ellipse, the parabola and the hyperbola, whose properties were investigated in minute detail, and without ulterior object.

In the intellectual awakening of Europe—the Rennaissance, say—the renewed intimate contacts with Greek mathematics and astronomy were of great meaning, stimulating both revolution and progress. Copernicus replaced the complex geocentric Ptolemaic system by the relatively simple heliocentric system which since has borne his name. Kepler, probing into older observations, and with more effective instruments making new observations, and bringing measurement more into the foreground, established that the fundamental fact was not uniform motion in a circle, but non-uniform motion in the ellipse, the properties of which by a kindly fate had been worked out and were ready to hand. Each planet moved round the sun in an elliptic orbit, with the sun in one of the two foci of the ellipse, the line from the sun to the planet sweeping over equal areas in equal times, and making the complete journey of the ellipse in a time related only to the mean distance of the planet from the sun.

Inevitably the question of the cause arose, and the assumption of a force exercised by the sun, in way of attraction, seemed to hold the key to the solution. The science—mathematical—of dynamics came into being at the hands of Galileo and Newton, and the stage was prepared for the momentous discovery of Newton. To the comprehension of this it may be well to present a few details.

It was taken for granted that a body free to move, if at rest would continue at rest, or if in motion would continue in unchanging velocity in a straight line, unless acted upon by some force, and that any change in such motion—evidence therefore of the action of a force—afforded a key to the measure of the force, nothing as yet being said of the existence of more than one distinct force. At the surface of the earth a body, freed from support, fell to the earth because of the attraction of the earth with a velocity incipient at the outset and increasing uniformly with the time measured from the beginning of the motion, the space traversed from the beginning being proportional to the square of the time. Thus the observed or calculated velocity

at the end of one second was found approximately to be 32 feet a second, at the end of two seconds to be 64 feet a second, and so on, while the space traversed in 1, 2, 3, 4, . . . seconds was found to be 16 feet, 64 feet, 144 feet, 256 feet, . . . in a calculation the assumption being that the attraction of the earth continued the same. It was taken for granted too that in the case of a body not falling from rest but moving in any direction, it would independently of this motion experience in one second a fall to the earth of 16 feet, in two seconds a fall of 64 feet, and so on. Thus the path of a bullet from a horizontal rifle would be a curve—not the straight line in which the bullet emerged from the rifle—which at the end of one second (say) would

Diagram to illustrate the motion of the moon about the earth.

be 16 feet below such a straight line. To Newton the motion of the moon was due in the main to the attraction of the earth, that is to say that in moving around the earth in approximately a circle it was constantly falling away from its line or direction of motion through falling constantly to the earth. He—for many reasons—was led to hold that the attractive power of the earth, acting as it were from its centre, diminished with the distance from the centre of the attracted body. He held conjecturally that this force varied inversely as the square of the distance, that is to say for a body two times as far away the attractive force would be ¼ as much, for a body three times as

far away this force would be 1/9 as much, and so on. Hence knowing the distance of the moon from the earth's centre, and the distance from the surface of the earth to its centre, he could test the conjecture, the falling body at the earth's surface recording the force of attraction corresponding to a distance equal to the radius of the earth. Thus if P, Q, in the accompanying figure, are positions of the moon corresponding to a certain interval of time and E the centre of the earth, the velocity of the moon being known, it is seen that, were it not for the earth's attraction the moon would have been at M, on the tangent to the moon's orbit, approximately a circle. Consequently if Q is not far from P, so that MQ has virtually the same direction as PE, MQ measures the distance through which the moon has fallen to the earth. Now it is not difficult to compute MQ, in view of what is known about the distance of the moon and the time of a revolution. When calculated, Newton, in time, found that this corresponded to a force which varied inversely as the square of the distance. But in this we see only the beginning of his adventure. He then devoted himself to the task of the study of the motions of the planets about the sun, inventing a mathematical instrument which allows one to drop the reiterated "approximate," namely the infinitesimal calculus. He showed that the hypothesis of an attraction varying as the square of the distance of a particle from an attracting centre required the elliptical orbit, and that in like case the elliptical orbit, about an attracting centre at a focus required an attraction varying as the square of the distance. Thus his theory was in accord with the findings of Kepler. The century following Newton's discovery and invention was in the main in this field, a development of the ideas started and quickened by him. The great works of Lagrange and Laplace are with the fundamental *Principia* of Newton the supreme testimony to the rôle of mathematics in astronomy.

While Newton's theory in the first instance considered the attraction of a body on a particle, or the motion of two bodies, as the earth and the moon, or the sun and the earth, under their mutual attraction, this simplicity, though presenting the major feature of (say) the earth's motion under the attraction of the sun, is perturbed by the fact that in this case the earth's motion is affected by the attraction of other bodies, as the moon and the other planets. The so-called

irregularities in the movements of the heavenly bodies that worried the early astronomers have their source in this circumstance. The equations that arise when the complex actuality is treated, admit in general only approximate solutions, through the consideration of infinite series, and somewhat ironically, the partial series which gives the approximate solution is the rejected system of epicycles earlier devised. To make a simple illustration, if

$$\theta = 3t + 0.2 \cos t$$

gives the position θ of a body at time t, the term $3t$ supplies what the result would be under uniform velocity 3, and the term $0.2 \cos t$ would be supplied by a simple cycle of radius 0.2.

A beautiful additional confirmation of Newton's theory, through a skilful application of mathematics, was the discovery of the planet Neptune. Certain irregularities in the motion of Uranus seemed to call for the action of some body not known to exist. Computations by Leverrier pointed to the existence of a planet, which at a stated time would be in a stated place. The obedient telescope revealed the small appearing, though actually large, outer planet which was given the name Neptune. Independent computation by Adams led to the like conclusion.

Time will not permit anything but the mere reference to the recent speculations, resting on mathematical investigation, on the character of space, its boundaries, and its extent, and to the revision of ideas implied in the outstanding work of Einstein. Yet, perhaps, sufficient has been said to indicate that mathematics, finding indeed a sustained stimulus through the facts of astronomy, has played a leading part in the construction of the edifice that springs to mind at the mention of Astronomy.

Manilla, Ont.

COMPASS DIRECTIONS IN THE TELESCOPE

By H. Boyd Brydon

THE compass directions of the sky as seen in an astronomical telescope differ from those directions as seen with the naked eye. Conventionally it is said that in the telescope they are "reversed" or "inverted". The two words do not express quite the same idea, but here, both mean that as one looks into the eyepiece north is at the bottom of the field, south at the top, east on the right hand and west on the left.

Unfortunately the convention does not always hold, for although individual stars may be moving upward or downward, to left or to right, as they do in the neighbourhood of the celestial pole, all are moving in the same direction,—westwards. Thus it is correct to say that in the sky or in the telescope "westwards" is the direction in which any star moves. It is not correct to say that westwards is some particular direction referred to any observer.

There are additional restrictions. The statement that in the field of view of a telescope the compass directions are reversed is true only in the case of a refracting telescope, having a Ramsden or a Huygens type of eyepiece, directed to a point in the sky close to the meridian and south of the zenith. When the telescope is a reflector, or is used with a diagonal eyepiece, or when it is directed to a point some distance from the meridian or north of the zenith the rule does not apply.

The attempt to clarify the situation by means of a set of diagrams such as A, B and C in the adjoining figure is but partially successful, for these restrictions, apply with equal force to the diagrams as to the rule they are intended to illustrate.

Yet there is a rule, a simple rule for determining these directions which applies without exception, in all circumstances, with any telescope, having any eyepiece, in either hemisphere and for an image viewed directly or by projection. The rule depends upon two facts: first, that in their daily passage across the sky the stars move continuously westward; second, that a north-south line is always perpendicular to one running east and west.

The rule may be stated thus: The telescope being stationary,

stars in its field drift westwards. The east-to-west direction being thus found, by swinging the telescope at right angles to it towards the elevated pole and noting the direction in which the stars in the field appear to move, the northward and southward directions are also fixed, for if the upper end of the telescope be moved northward the stars in the field must appear to move southward and conversely.

When the compass directions have been determined in this way for the telescope field under observation, the instructions implied in the phrases north (or south) preceding (or following) a known

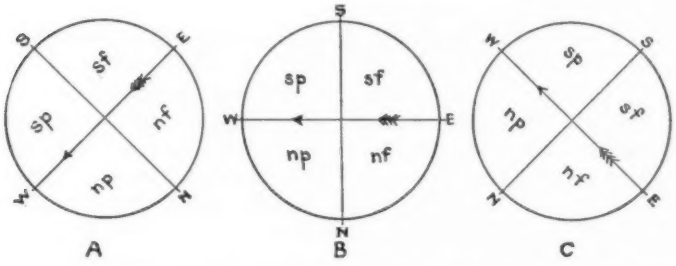

Fig. 1—The circles represent three telescope fields: A, in the south-east, stars rising; B, in the meridian, stars culminating; C, in the south-west, stars setting. N, E, S, W are the north, east, south, west points of each field. Stars drift across each field as the arrow flies. Stars in area sp, (south preceding) cross the field ahead and to the south of a star in the centre; in nf, (north following) after and to its north. Similarly np means north preceding; sf, south following.

star as they relate to the position of an object sought become of practical value. "Preceding" means that the object lies to the telescopic west of the known star. That is, its right ascension is less than that of the star. "Following" has, of course, the opposite meaning. "North" means that the object lies to the telescopic north of the known star; south, to the south of it.

In this connection a suggestion may be offered to those who are beginning to use star maps and star charts. In general the maps in a star atlas such as Norton's, being prepared for direct comparison with the sky, are drawn with north at the top and west at the right hand side. Star charts for use at the telescope, however, are usually drawn in the reversed position with south at

the top and west to the left. It is then of importance to become familiar with these differences of direction in maps and charts and in the telescope, particularly when a diagonal eyepiece is used. In all cases the use of the rule given above will show how the directions are related in the telescope. Proper allowance can then be made for these differences by noting the way in which an object *precedes* or *follows* a known star.

It is sometimes convenient to reverse a chart by transferring the stars directly to the back. The same effect can be had when a chart-lantern is used by putting the back of the chart outwards in the carrier frame. The former is the better plan as it allows of the chart being held in a position corresponding to that in which the stars appear in the field of view.

When the telescope is not mounted equatorially or is without hour and declination circles it has been found convenient to have at hand a number of diagrams such as those in the figure, each conforming with the compass directions as they appear in a typical field of the telescope for the kind of eyepiece used. The appropriate diagram slipped onto the eyepiece tube and properly oriented will serve effectively to indicate these directions in the field under observation and thereby facilitate finding the object required. Similar diagrams have been found useful in estimating the position at which an occulted star will reappear.

January 1941.

AMATEURS AND HANDBOOKS

By Walter Scott Houston

IT is a rather common belief that the amateur astronomer was an unimportant figure during the last century and that he has attained full stature only in this last decade. The revival of popular interest in astronomy and the newspaper publicity of the last dozen years have encouraged this feeling. It was not many years ago that one could find many professional observers who would openly deride the efforts of the owners of small lenses.

To many it seems logical that the three- to six-inch lens of the amateur is helpless beside the larger instruments of the great observatories; and especially was this true in the United States where many astronomers feel frustrated unless they operate one of the world's giant telescopes. Even the late E. C. Pickering was somewhat a victim of this delusion, for, when he first suggested variable star observation for private individuals he assumed his programme would appeal mostly to women who wished to keep up a cultural connection with the diluted science of their college days. But had Pickering turned one steady glance upon the amateur, and especially upon the English amateur, he would not have been so surprised when his programme was taken over by men and prosecuted with an enthusiasm that eventually rivalled the English amateur.

A survey of the last century of amateur astronomy shows the amateur continually making recognized contributions to the science. Although his spheres of activity have altered so he no longer makes the same kind of observations, his results have been at all times necessary to the progress of the science. Such a survey must properly start in England with Admiral William Henry Smyth. He is virtually unknown in the States but his "Celestial Cycle," of which the "Bedford Catalogue" formed the second volume, is the ancestor of all of our amateur handbooks. In this volume, in a style ornamented with a profusion of classical allusions, a mixture of racy nautical terms, and some brackish poetry, Smyth catalogued the double stars and nebulae within reach of his six-inch refractor. He had observed and measured all the objects himself, and, as

Robert Grant Aitken says, the catalogue was "justly popular for . . . descriptions of the double and multiple stars, nebulae and clusters, of which they treat, and . . . still anything but dull reading."

But popular and interesting as the "Cycle" was, it has little more than antiquarian usefulness to-day because it treats almost entirely of one class of phenomena—the double stars. In 1844 these were the only extra-solar phenomena which were at all interesting.

So matters stood, and amateurs were double star observers, until 1860 when Smyth published his "Speculum Hartwellianum" which is even less known to the American amateur. Here he re-examines various objects from the Bedford Catalogue and comments upon the progress of astronomy since 1844. And what a change that was!

The period 1844 to 1860 had seen the discovery of the sun-spot cycle, stellar parallax had been measured, U Geminorum was perplexing observers, and the Earl of Rosse's reflector had started the great nebular dispute. The Bedford Catalogue lists but four asteroids, the 1860 volume catalogues fifty; and the position angle and distance of Mizar were being read off from photographic plates. A sheaf of paper and a pencil had captured Neptune; and, the variable stars had led observers to another "peak in Darien."

So when Smyth opened an amateur observatory in 1859 his instructions to his observer Pogson mark the transition from the old to the new amateur. To be sure the already interesting double stars were to be observed, but the main efforts were to be in the fields of asteroid hunting and variable stars. Thus the double star amateur passed from the scene, and the asteroid hunting proved to be transient. Dawes, Burnham, and Clark did excellent work but the arrival of the big refractor made amateur efforts futile. None the less the handbooks followed the example of Smyth and devoted their pages to long lists of double stars, many of which had no interest, while the newer items of amateur interest were itemized in footnotes. Olcott, Proctor, Ball, Serviss, Barns, and even the massive "Splendour of the Heavens" devote too much attention to the double stars.

Although the handbooks tell relatively little about it, the modern amateur has entered new fields. His occultation programme has

been most useful; he has captured almost all the bright comets and bright novae. His contributions in the fields of variable stars and meteors will be valuable as long as men study the stars. In America the rise of the cheap home-made reflector has placed powerful equipment within reach of any observer who really wants to work. The number of such instruments runs well over 25,000 and from the ranks of the telescope makers have already come several excellent amateur astronomers.

With this renewed activity the amateur is spending more money and consequently attempting new research. The AAVSO now sponsors a photographic programme, a visual search for supernovae, and a novae programme. Amateurs are getting light-curves in two colours; they have built microphotometers, and other types of photometers. They are attacking the magnitudes of double stars with variable gratings. The amateurs who are blessed with money are erecting observatories that are professional in equipment, and here may be placed such institutions as the Hulbert-McMath solar tower, and the late Dr. Cook's establishment at Wynnewood, Pa. The first Schmidt camera in America was built by an amateur.

The modern handbook for such an amateur must distinguish between phenomena which have a merely historical value and those which are objects of amateur research.

For example, there is need for a concise account of what may be done in lunar and planetary research. Comet seeking demands a chapter upon methods, charts, international code, and the like. The section on meteors and meteorites will include several chapters. The variable stars need pages dealing with methods, classifications, information about individual stars. Here there should also be much material on instruments and methods of photometry. The chapter on double stars will be short and mainly historical.

There should be many pages on photography and methods of measuring the plates. Astronomical charts and their uses will be discussed, and a brief use of the ephemeris will be included. A section on graphical computation (after Rigge) must be inserted, and there will be tables for precession, magnitudes of nebulae and stars, data for selected photometric areas, cross indexes to Herschel and NGC numbers, and much such information which at present the amateur must painfully cull from a multitude of sources.

Finally there must be a bibliography of useful sources and some evaluation of the various professional publications.

The modern amateur is not inhibited by the "bigness complex" that paralyses the average small college observatory in the United States. These schools compare their six-inch telescopes with the giants at Yerkes and Mount Wilson and conclude that research is impossible with such feeble equipment. Lacking a three-foot mirror they teach a survey course in the mathematics or physics department, and once a term dubiously point out a few constellations. At the same time, the amateur astronomer with comparable equipment, unashamed of his limited equipment, proceeds to do first-rate work. His biggest handicap is that he has no handbook which is up to date.

University of Alabama.

A TIDAL ATTACK ON THE CEPHEID PROBLEM

By William A. Luby

1. *Introduction.* The outstanding characteristic of Cepheid variables is their punctuality. Considering this feature, Miss Clerke wrote: "Orbital motion in one form or another prescribes the flow of change." (Problems in Astrophysics, page 320). If this judgment be correct, the Cepheid Problem is a dynamical one and the correct application of dynamical principles to it should yield the solution. This paper uses those principles, regards a Cepheid as a close binary and aims to interpret Cepheid phenoma on a tidal basis.

2. *Hypothesis.* In Table I, the period, the mass, and the radius of the nine representative Cepheids are as given by Russell, Dugan, and Stewart (Astronomy, page 768). Calculation gives the numbers in the last column. These show that a particle would revolve outside the surface of six of these Cepheids, on the surface of one and just inside the surface of two. But the method by which the masses and radii of these stars were calculated leaves a considerable margin of error. Moreover, a massive body would revolve at a greater distance from the primary than would a particle. Hence it is quite possible that in each of the nine cases a companion of small mass compared to the primary would revolve outside it.

This leads to the hypothesis of this paper. (*a*) A Cepheid is a binary with a period of revolution equal to the light period. The companion is assumed to be of relatively small mass, but of greater density than the primary, close to the primary, and either dark or faint. (*b*) The cause of the light variation is the rise and fall of the enormous primary tide on the bright star. Here only the tide raised on the side of the primary near the companion is important. The other tide is so small that its effect is negligible. (*c*) The main cause of the velocity variation is due to the rise and fall of the tide raised on the primary, not to the orbital motion of the primary. The latter cannot be wholly neglected. It will be shown in Section 12 that the orbital velocity of the primary is a vital factor in the velocity lag at light maximum and at light minimum.

3. *Motion of the Tidal Wave.* Figure 1 represents roughly the motion of the tidal wave with respect to the primary. For simplicity the line of sight is assumed to be in the plane of the orbit or to make a small angle with it. If the line of sight is perpendicular to the plane of the orbit the observer would see no light or velocity variation even though the tidal disturbance were of vast magnitude.

TABLE I

Name of Star	P in days	Mass Sun = 1	R of star in km. $\times 10^6$	a for particle with period P in km. $\times 10^6$
1. Delta Cephei....	5.37	10.5	18	19.647
2. Eta Aquilae.....	7.18	13	24	25.605
3. Zeta Geminorum.	10.15	18	30	35.947
4. Lambda Carina..	35.52	50	80	116.470
5. X Cygni.....	16.38	26	48	55.905
6. Y Oph.....	17.12	28	50	58.99
7. R R Lyrae.....	0.57	4.6	4	3.452
8. S U Cass.....	1.95	6.3	9	8.415
9. α Ursa Minoris...	3.97	8.5	15	14.982

Cepheids whose orbits make large angles with the line of sight will be considered later.

The velocity variation would arise as follows. The motion of each particle of the material of the wave is up or down along the radius through the particle. The integrated component of this velocity parallel to the line of sight is what the spectrograph records.

4. *The Light Variation.* Figure 1 shows light minimum as occurring in position B of the wave. It is there just becoming visible as it comes from behind the star. Light maximum occurs at E and velocity maximum near it. After leaving F the wave

becomes eclipsed by the star. Thus the time interval from B to E is less than that from E to B. For Cepheids of low density the return to equilibrium takes time. These factors give the usual slow descent of the light curves and the slow rise of the velocity curves. If the Cepheid is of relatively great density as is R R Lyrae, there is a more rapid return to radiative and gravitational equilibrium giving a flat velocity minimum. Thus eclipse effects

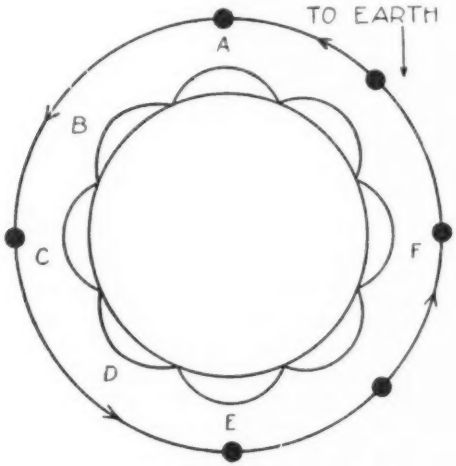

Fig. 1.—Motion of Tidal Wave.

and the density of the Cepheid determine the character of the light curve from maximum to minimum usually giving a slow fall compared to the rise.

5. *The Height of the Tide.* Before taking up further details of the light curve the possible height of the wave will be considered. In particular, it is necessary to determine whether it is high enough to account for the velocity variation. To do this, preconceptions about terrestrial tides must be ruled out and what may be called the "equilibrium point" between two bodies examined. The equation

$$\frac{81}{x^2} = \frac{1}{(240{,}000 - x)^2}$$

determines the equilibrium point between the earth and the moon. There the gravitational attractions of the two bodies are equal. This point is 216,000 miles from the centre of the earth. In the case of a Cepheid having a small companion the "equilibrium point" may be below the surface of the bright star. This is shown for δ Cephei by the numbers of Table II.

TABLE II

DELTA CEPHEI

Mass of Companion Sun's mass = 1	Radius of Orbit in km.	Distance of equil. pt. from centre of star
.04	19,672,000	18,547,000
.09	19,703,000	18,034,000
.0955	19,706,000	18,000,000
.10	19,709,000	17,972,000
.16	19,746,000	17,536,000

The calculated radius of δ Cephei as given in Table I is 18,000,000 km. When the equilibrium point passes below the surface of the bright star ordinary tidal effects would fail and most of the material of the bright star outside the equilibrium point would be attracted by the near-by companion more strongly than by the bright star itself. Herein lies a dynamical foundation for enormous tides.

Under the hypothesis tidal friction makes it inevitable that the companion gradually approach the primary. As long as the equilibrium point is outside the surface of the primary ordinary tidal effects take place but when the point passes within its boundary then Cepheid phenomena arise. Polaris with its small light change may be either a Cepheid with a very small companion or one in which the equilibrium point is outside the primary or at any rate near its surface.

In the case of δ Cephei the *approximate* height of the tide required to account for the observed velocity is $\frac{5.37}{4} \times 86{,}400 \times 19.7$ kilometers. This is of the order of two million kilometers. Here 5.37 days is the period and 19.7 km. per second is the half amplitude of the velocity curve.

6. *The volume of the tide.* A first approximation to the volume of the tide can be made by supposing that the volume of the half ellipsoid nearest the primary equals half the volume of the star. This gives

$$\frac{2}{3}\pi ab^2 = \frac{2}{3}\pi R^3. \quad . \quad . \quad . \quad . \quad . \quad (1)$$

According to Section 5 the value of a is, in round numbers, 20,000,000 km. Substituting these values in (1) and solving, $b = 17{,}076{,}000$ km. The volume V_1 of the material displaced either above the normal boundary of the star or below it is approximately

$$V_1 = \frac{2}{3}\pi R^3 - \frac{2}{3}\pi Rb^2 \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The volume of the sun is $V_2 = \frac{4}{3}\pi(6.953 \times 10^5)^3$. Dividing V_1 by V_2 gives 937.

Of this last volume probably one half of it is raised above the normal boundary of the star. This makes the volume of this portion of the tide wave something like 468 times the volume of the sun. As the volume of δ Cephei is 17,350 times the volume of the sun, it can be seen that the tidal disturbance of even a small companion has an enormous volume.

7. *The Change in Spectral Class.* The volume of the wave as has been seen is enormous. It cannot be composed wholly of surface material but must be made up of material from the outer layers and from lower-lying ones which are hotter and more luminous. The change in spectral class would be a necessary consequence.

8. *The light variation of Delta Cephei.* The adjacent figure for δ Cephei shows four critical positions of the tide. Here presumably the line of sight makes a small angle with the orbit plane. Light minimum occurs at C, light maximum at E. At F the wave is about to pass from sight behind the star. From C to E is 29 per cent of the light period. Here eclipse of the wave occurs but the rate of return to radiative and gravitational equilibrium determines the character of the light and the velocity curves from maximum to minimum. For dense Cepheids the minimum is flat for those of small density the descent to minimum has a nearly

uniform slope. These factors along with the unequal time intervals determine the slow fall of the light curve as compared to its rapid rise. With possibly a few exceptions the interval from minimum to maximum is shorter than that from maximum to minimum.

The passage of the wave behind the star near F may be marked by a "pause" in the light curve. The cause of this may be described by saying that the visible hemisphere is then increased by

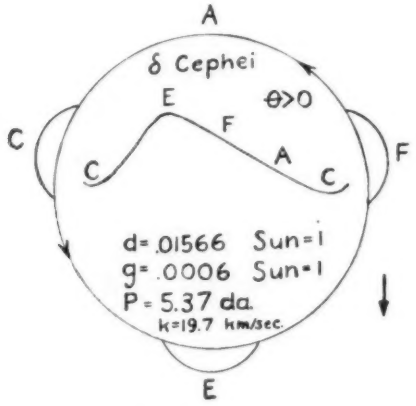

Fig. 2.—Tidal Diagram for δ Cephei.

a cross section of the wave perpendicular to the line of sight. For δ Cephei we may approximate the cross-section of the semi-ellipse as follows. Using the values of a and b found in Section 6 for δ Cephei the semi-ellipse $= \frac{\pi ab}{2}$ and the semicircle $= \frac{\pi R^2}{2}$. The ratio of these is 342 and 324. Hence as the wave passes behind the star the luminous area reaches a maximum. Consequently there should be a pause in the descending branch of the light curve at that point.

Now the epoch at which this pause occurs is vital. Light maximum should occur midway between light minimum and the pause. In the case of δ Cephei the pause should occur 58 per

cent of the period, or 3.11 days after light minimum. The evidence on this point will be presented in Section 11.

9. *Zeta Geminorum.* Figure 3 makes it possible to explain the light variation of those Cepheids which have nearly symmetrical light curves. If it be assumed that the plane of the orbit of ζ Geminorum is inclined at a large enough angle to the line of sight so that the wave is partially visible all the time, then the symmetry of the light curve would follow. The letters on the light curve and those on the wave make clear the existing relations more effectively than does any verbal description.

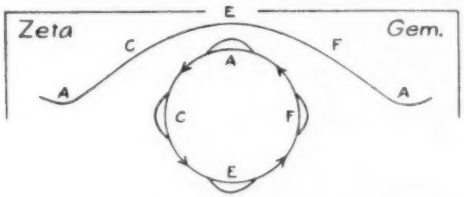

Fig. 3.—Light curve and Tide for ζ Geminorum.

10. *The velocity variation.* In Figure 1 as the wave passes from C to E the sudden rise of the velocity from minimum to maximum should and does occur. To understand the velocity change after the maximum velocity of approach, it is necessary to remember that the wave is not a water wave which would subside as soon as the disturbing force is removed. Instead, it is a wave in gaseous, elastic, material sinking back to equilibrium in a low gravitational field.

Whether this return is slow or rapid depends on the density of the star and its surface gravity. If these are relatively great, the return is rapid and the velocity curve may exhibit a flat minimum as will the light curve. If the density and the surface gravity are relatively low, the return to gravitational equilibrium is slow.

Thus the rise and fall of the visible wave explains over half of the velocity curve, 58 per cent in the case of δ Cephei. When the wave becomes invisible there is for dense Cepheids a flat velocity minimum and for those of low density a slow return to gravitational equilibrium of the disturbed visible hemisphere and

a slow recessional velocity continued to near the minimum. It is thus easily seen why the slope of the velocity curve is less after the maximum velocity of approach than before it.

11. *Interpretation of representative light curves.* Joy gives the adjacent light and velocity curves for R S Cassiopeiae (Astrophysical Journal, Vol. 86, 1937). The flat light minimum is duplicated in a similar velocity minimum. The "conventional" velocity curve must be disregarded and the curve indicated by the rather few observations considered instead.

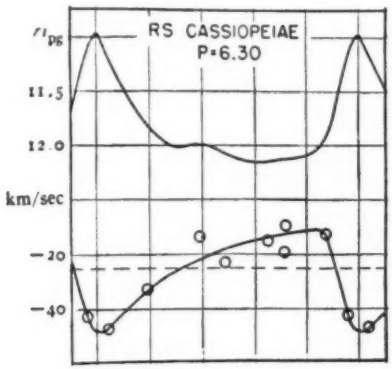

Fig. 4.—Light and Velocity curves of RS Cassiopeiae.

The hump on the descending slope of the curve for η Aquilae may be interpreted as indicated in the last two paragraphs of Section 8. From light minimum to light maximum is 32 per cent of the 7.18 day period, or 2.29 days. In 2.29 days more the wave should anish behind the star; that is, the interval from minimum to the end of the hump should be 4.58 days. Inspection of the curve shows that the position of the hump is in excellent agreement with this.

If the slight hump still farther down is not the result of errors, it may be interpreted as due to the minor tide. This tide is in the centre of the visible hemisphere when the major tide is in the centre of the invisible one. The minor tide should be most noticeable one-half the period, or 3.6 days after light maximum. Inspec-

tion of the graph shows that the position of the second hump is in good agreement with this.

The light curve of δ Cephei by Stebbins shows two small humps. From light minimum to light maximum is 29 per cent of the period or 1.56 days. The interval from minimum to the end of the first hump should be 58 per cent of the period, or 3.12 days. Inspection of the graph shows that the position of the first hump agrees with this interpretation.

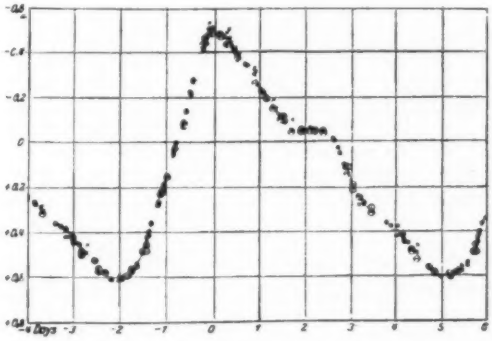

Fig. 5.—Light curve of η Aquilae (by C. C. Wylie, Ap. J. vol. 56, p. 225).

The second hump, if due to the minor tide, should occur half the light period, or 2.69 days after light maximum. Inspection of the graph shows this to be the case.

The foregoing pauses in the light curve can scarcely be due to errors. The more accurate the light measures, as are those for η Aquilae, δ Cephei, and Hertzprung's curve for S Sagittae the more clearly do the two humps appear. Of the 107 light curves given by Joy, nineteen show the first pause at about the proper time. Four others one-half the light period after maximum show the second pause which appears to be due to the minor tide.

12. *The velocity lag.* A particle moving near the surface of δ Cephei in a period of 5.37 days would have an orbital velocity of about 266 kilometers per second. Table II gives the probable

mass of the companion as about 0.16 of the mass of the sun. The momentum equation is

$$m_1v_1 = m_2v_2$$

Hence, $10.5v_1 = .16 \times 266$

and $v_1 = 4$ km. per sec.

This would be an approximation to the orbital velocity of the primary.

How such an orbital velocity is involved in the radial velocity can now be considered. In the orbital motion of δ Cephei, for example, when the secondary moves toward the observer, the

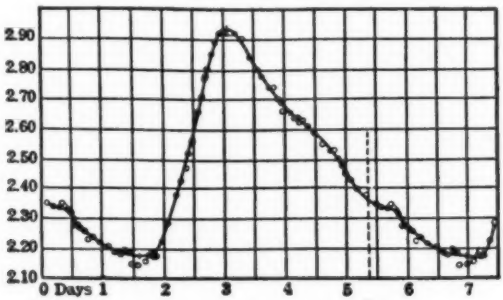

Fig. 6.—Light curve of δ Cephei.

primary moves away from him and vice versa. This means in Figure 1 when the wave is on the hemisphere ACE the primary is moving away from the observer and when it is on the hemisphere EFA the primary is moving toward him.

Near C the orbital velocity of the primary is a maximum while the velocity of rise of the wave is zero. Hence the net result at light minimum should usually be a positive lag. Of 155 Cepheids 125 have a positive lag, 3 a zero lag, and 27 a negative one. (Joy, Astrophysical Journal, Vol. 86, 1937). Thus 81 per cent are in agreement with the preceding discussion.

Light maximum occurs at E of Figure 1 and there the velocity of rise of the wave is a maximum while the orbital velocity of the primary goes through positive, zero, and negative values. The net result would usually be a positive lag or a zero one. In Joy's list

of 155 Cepheids, 129 have a positive lag at maximum, 15 a zero lag, and 11 a negative one. Thus 92 per cent of these agree with the foregoing discussion.

As to the negative and zero lag at light minimum and light maximum there may be other factors than the two principal ones considered. Some possible factors are those numbered 1 to 6 in Section 14.

13. *The constancy of the light period.* Changes of period, decreases, are known for only two Cepheids. It has required over a century of observations to establish the change for δ Cephei. It is well known that tides on a primary caused by a secondary, will, under certain conditions, increase or diminish the distance between the bodies (Moulton, Introduction to Astronomy, 1916, pp. 455-456). Cepheids are giant stars and it has been shown that such stars have little or no rotation. Hence the change of period caused by tidal friction would be a decrease for Cepheids.

The mean density of δ Cephei is 0.00846 on the water scale. The surface density must be far less than this. Hence the total mass of the wave is small and tidal friction is minute. Apparently the work done through tidal friction is so small that when subtracted from the kinetic energy of the companion, $E = \frac{mv^2}{2}$, its effect on the period of the latter becomes perceptible only after a long interval. But tidal theory admits of no compromise. Given time enough, the light period of every Cepheid should decrease.

If a Cepheid is found to have an increasing light period, then it would follow from tidal theory that the period of rotation of the primary is less than the light period.

The calculated decrease in the period of δ Cephei on the pulsation hypothesis is, according to Eddington, 500 times the observed decrease. This is in harmony with the tidal hypothesis for a pulsation would be a vastly greater disturbance than is the tidal one.

14. *Variant factors.* Joy lists four Cepheids which have a slow rise of the light curve and a rapid fall. Up to this point the explanation of the light and velocity curves could be based on circular orbits or at least on those which are nearly so. If it is necessary to explain these four unusual light curves and their velocity curves also, a consistent explanation might be based on the following

variant factors: (1) Elliptic orbits, (2) the value of the eccentricity, (3) the position of the line of apsides, (4) the direction of the orbital motion, (5) whether the primary is at the nearer or the farther focus, (6) the value of i.

15. *The Period-luminosity law.* If the tidal hypothesis of Cepheids is sound, it should be possible to derive from it the period-luminosity law. The derivation is obtained as follows:

The companion is small and revolves close to the primary. Therefore r varies as a which equals $\sqrt[3]{P^2m}$; that is

$$r = C_1\sqrt[3]{P^2m} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The luminosity of a hemisphere varies as the square of its radius. Hence if B is the average surface brightness, the light given out by the visible hemisphere of a Cepheid is

$$L = 2\pi r^2 B \quad . \quad . \quad . \quad . \quad . \quad (2)$$

From (1) and (2), $$L = 2\pi B C_1^2\sqrt[3]{P^4m^2} \quad . \quad . \quad . \quad . \quad (3)$$

This last is the period-luminosity law in terms of the period, P, the mass, m, and the surface brightness, B, of the Cepheid.

B varies with the spectral class and is greatest for Cepheids of short period; that is, as P and m increase, B decreases and vice versa. Thus the change in P and m tends to compensate the variation in B. A remarkable approximation for this can be worked out as follows:

Clearly $$L = (2.512)^M \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Assume tentatively that

$$(2.512)^M = 2\pi B C_1^2\sqrt[3]{P^4m^2} = (P^{\frac{4}{3}}m^{\frac{2}{3}})^k \quad . \quad . \quad (5)$$

From (5) $$M = \left(\frac{k}{3}\log P^4m^2\right) \div .4 \quad . \quad . \quad . \quad . \quad (6)$$

and $$k = .4M \div \frac{1}{3}\log (P^4m^2) \quad . \quad . \quad . \quad . \quad (7)$$

Using P, M, and m for δ Cephei in (7) gives $k = .534$ . . (8)

This gives for δ Cephei the following values:

log P	log m	abs. mg.	M	k
.73	1.02	−2.2	$-4.13k$	.534

A mean value of k for twenty-two Cepheids was obtained as follows: The same calculation as that for δ Cephei was made

for the other eight Cepheids of Table I. In addition to these nine, thirteen other Cepheids whose periods and magnitudes are given by Shapley (Handbuch der Astrophysik, B VI, S.219). The masses of these thirteen were taken from the mass-luminosity curve. These last were selected in order to give a larger range and a better distribution of periods. The same calculation was made for these thirteen as for the first nine. Inspection of all the results showed that the calculated absolute magnitudes would be in good agreement with the observed values if $k = .55$.

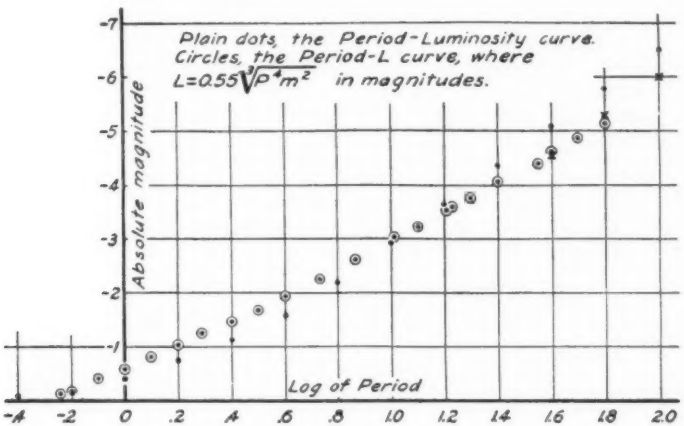

Fig. 7.—Period-Luminosity curve.

In *Star Clusters*, page 130, Shapley gives the coordinates of the period-luminosity curve. These values and the calculated magnitudes were plotted in the graph against the log of the period. This gives a total of 22 points. Shapley says the magnitudes of the Cepheids with periods in excess of 30 days should be reduced by half a magnitude. This reduction is shown by crosses for the Cepheids having the three greatest periods. The agreement of the 22 points with Shapley's coordinates is striking.

It is important to note that the period-luminosity curve was originally derived by a quite different method from that here considered.

16. *Summary.* Dynamical principles have been applied to the hypothesis of Section 2. A strict application of those principles has accounted for the light variation, the velocity variation, the velocity lag at light minimum and at light maximum, the various shapes of the light curves, and other Cepheid phenomena. The period-luminosity law has been derived directly from the hypothesis. A simple modification of it has been found to be in remarkable agreement with the observations over an extremely wide range. Thus the tidal attack on the Cepheid problem appears to offer a consistent explanation of Cepheid phenomena.

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TWO USEFUL TELESCOPE ACCESSORIES

By H. Boyd Brydon

THE recent transit of Mercury was observed at Oak Bay Observatory by means of a solar camera and a viewing screen of somewhat novel design. Being effective, simple to construct and inexpensive, their description may be of interest.

Solar Camera. The solar camera, (Fig. 1) consists of a cylinder

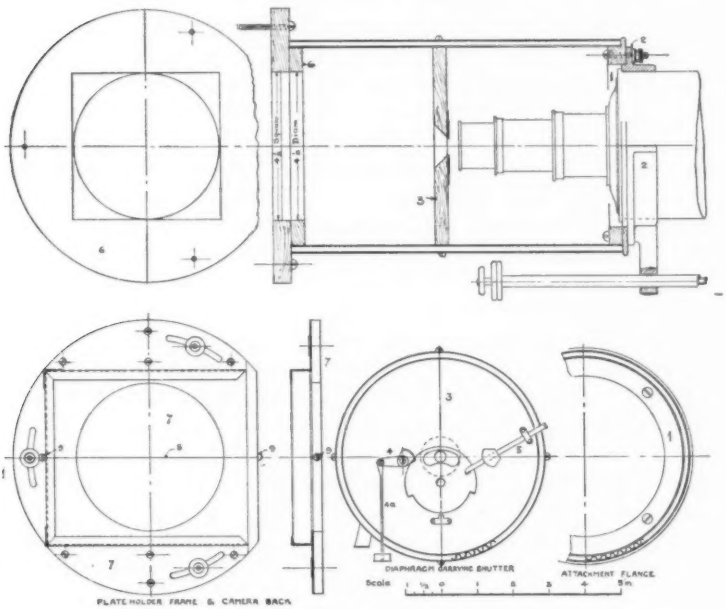

FIGURE 1.—CAMERA FOR SOLAR PHOTOGRAPHY.

5½-inches inside diameter by 9½-inches long made of single-surface corrugated paper with the corrugations outside and parallel to the axis. The joint is made by butting the edges together under a 1-inch wide cover strip of the same material placed with its corrugations

meshing with those on the outside of the cylinder. The joint is made more easily if the cover strip be glued to one side and allowed to dry before the other side is secured. The cylinder is stiffened by winding, spirally and firmly, but without crushing the corrugations, three thicknesses of 2-inch wide heavy gummed paper of the kind used in fastening parcel wrappings, each layer crossing the one below it. A firmer bearing for the screws which secure flange 1 and diaphragm 3 to the cylinder body is obtained by first filling the corrugations at these points with plastic wood.

The length of the cylinder is determined by the distance from the telescope eyepiece of a screen on which is carefully focussed an image of the desired size, in this instance by the convenient diameter of the sun's image thrown on a 5 x 4 plate by a ×60 eyepiece.

The camera is attached to the telescope by four 8/32 round-head brass machine screws, screwed into flange 1 from the inside and set in glue or seccotine to prevent them from turning when the milled nuts, retrieved from the terminals of dead No. 6 dry batteries, are tightened. The flange, secured to the end of the cylinder by four No. 6 round-head wood screws is made of layers of "cigar box cedar", glued together with the grain crossed. The wood used in cigar boxes is light, of fine straight grain, true to thickness and empty cigar boxes for the purpose may be had for the asking.

In the present instance flange 2 on the telescope tube, here 4 3/16-inches outside diameter, is of cast aluminium, halved, bored, faced and drilled to dimensions. Brackets on it support the clamp and slow-motion rods. In the case of a Newtonian reflector a suitable saddle flange fitting the telescope tube would replace flange 2 as here shown.

Well clear of the eyepiece when focussed is a diaphragm 3, made similarly to flange 1, and held in place by four No. 6 round-head wood screws, on which is mounted the shutter, taken from an old box camera. The original operating lever 4, and motion stop 5 for focussing are extended as shown for operation from outside the cylinder. To permit removal of this diaphragm, the rod 4a, for operating the shutter is attached to the end of the original operating lever by a "snap fastener" soldered to each.

It was found necessary to enlarge the aperture of the shutter to 7/16-inch diameter, to clear the cone of light rays from the eyepiece

and to reduce the time of exposure by reducing the length of the opening in the moving blade. Experience has indicated the desirability of using a shutter of which the speed can be adjusted more readily.[1]

The flange 6, which is glued in place has a recess 4⅛-inches square towards the photographic plate to carry the filter to be used. The filter is prevented from falling out by the camera-back 7, secured to flange 6 by three 8/32 screws. The holes for these screws in the camera-back are slotted as shown to allow it to be rotated so that the wire 8, shall lie in a true east-west direction, found by letting a sunspot of the sun's limb trail along it. The orientation of the image is thus imprinted on each negative irrespective of the exact position of the plate holder in the camera-back. Flange 1 is not finally secured to the cylinder body until, with the holding screws central in the slots of the camera-back, this adjustment is practically correct. Strong black linen thread was used originally for the wire 8, but was found to be far too thick and was replaced by a length of No. 36 copper wire. The ends are secured under the round-head screws 9, 9.

The face of flange 6 and the seat for the plate-holder on the camera-back are covered with black broadcloth glued in place. After three coats of shellac varnish on the outside and two on the inside of the cylinder, the inside between the connecting flange 1 and the diaphragm 3, is painted one coat of flat black oil paint and between diaphragm 3 and flange 6 is lined with black velveteen glued in place.

Focussing is done by the focussing screw of the telescope, the image being viewed for that purpose either on a focussing screen of finely-ground glass carried in a frame slipped into the position of the plate-holder or in the plate-holder itself. If the distance of the focussing surface in the separate screen corresponds exactly in depth with the surface of the plate in the plate-holder, the first arrangement seems preferable as it simplifies manipulation. Correct focus is

[1]This shutter has now been replaced by an air-operated shutter from an old rapid rectilinear lens combination of a "post-card" size Kodak. Its speed is adjustable from "time" to 0.01 second. The Rev. W. M. Kearons in an article on solar photography in *The Telescope*, vol. 7, p. 52, 1940, recommends a Compur shutter having steel blades, ordinary shutters being too easily damaged by the intense heat.

insured in either case by observing that pencil marks drawn on the ground glass and the details of the projected image itself are equally sharp. A fairly high-power magnifying glass, say ×3 or ×5, should be used for this.

On the back of flange 6, that is, towards the object-glass of the telescope, is fixed a white card target in line with the optical axis of the finder. When the image, correctly focussed, is in its proper position on the main focussing screen, the position of the small image projected by the finder is carefully outlined on this target. The exposure is made when the finder image fills the circle drawn on the target.

Observing screen. The observing screen, (Fig. 2), is attached to

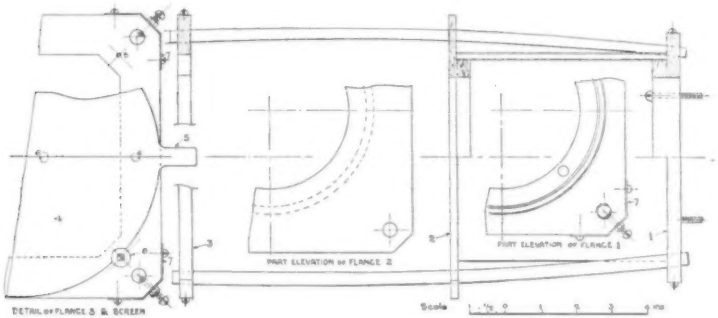

FIGURE 2.—SCREEN FOR OBSERVING SOLAR IMAGE BY PROJECTION.

the telescope as is the camera. This method of attachment is preferred to that in which the supports for the screen are clamped to the telescope draw-tube because it is stiffer, lighter, relieves the draw-tube and focussing mechanism of undesirable stresses and is freer from vibration. In construction it is simpler and inexpensive.

This accessory consists of a cylinder of corrugated paper, made as described above, 5½-inches inside diameter by 6-inches long, which affords a rigid connection between the two flanges 1 and 2, made of crossed layers of "cigar box cedar". Except for being bevelled on the corners as shown, these flanges are square on the outside, having sides 7-inches and 8-inches long, respectively.

Through 7/16-inch holes at the angles pass four 3/8-inch diameter wooden rods, 18-inches long, each secured in place in flanges 1 and 3 by an 8/32 machine screw passing through a nut soldered to a No. 16 brass corner iron 7 as shown. The hole in the flange is also tapped 8/32.

Sliding on these rods is the 8-inch square flange 3 which supports the screen proper. In flange 1 the centre to centre distance of the rods is 6-inches but in flanges 2 and 3 it is 7-inches. This difference in centres springs the rods and has the effect of stiffening the whole support.

The projection screen 4, is circular in shape. It is held lightly in place on the front face of flange 3 by four brass washers and No. 6 round-head wood screws 8. It can be rotated by the two tabs 5, 5, to orient it by aid of a fine line 6, drawn upon the prepared surface.

There is much room for personal preference as to that surface. It is important that it be flat, free from specks and other discolourations, smooth and without gloss. Among the materials which have been used with success are white bristol board, sheet tin or aluminium having a smooth glossless "duco" finish, a thin slab of plaster of paris suitably supported, a plate coated with magnesium carbonate, an unexposed photographic plate, etc. The writer's preference is a matt surfaced bristol board because its lightness, simplicity and cheapness permit it to be used freely for drawing upon as well as merely for projection.

For those who may wish to obtain information on the subject of astronomical photography the following works are recommended.

Astronomical Photography. by H. H. Waters, F.R.A.S., Gall and Inglis, London, W.C., 6 sh.

A Manual of Celestial Photography by E. S. King, Sc.D., Eastern Science Supply Co., Boston, Mass., $3.50.

The several booklets and monographs published by the research departments of the manufacturers of photographic materials such as Photographic Plates for use in Spectroscopy and Astronomy, Wratten Light Filters, etc., the Eastman Kodak Co.

2390 Oak Bay Ave.
Victoria, B.C.
Dec. 22, 1940.

AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS—THIRTIETH ANNUAL SPRING MEETING

By D. W. Rosebrugh, *Secretary*

THROUGH the invitation of Dr. Maud W. Makemson and Dr. Boris Karpov of the Vassar Observatory staff this was held at Vassar College, Poughkeepsie, N.Y., on May 30 and 31, 1941. Some sixty members and friends of the A.A.V.S.O. and thirty members of the Amateur Astronomers Association of New York City attended the meeting.

Our president, Dr. Helen S. Hogg of the David Dunlap Observatory, near Toronto, who has been Acting Director of Mount Holyoke College Observatory for the last year during Dr. Alice Farnsworth's absence on sabbatical leave, presided over the Council Meeting at 4 p.m., May 30. Mr. Leon Campbell, Recorder, reported that while the observations submitted by A.A.V.S.O. members had fallen to 60 per cent. of normal, yet the observations received have enabled him to plot the light curves of the important variable stars under study.

Mrs. David W. Rosebrugh, wife of the secretary, entertained the council members and their wives at a "hot dog roast" at her home on the outskirts of Poughkeepsie. As a result of this gastronomic experiment it may be reported that astronomers are as fond of this international delicacy as anyone..

In the evening the 12-inch refractor at Vassar Observatory was used to look at the moon, the cluster in Hercules and the ring Nebula in Lyra, while some of the more serious minded used the smaller instruments to observe variable stars and compare techniques.

At the Saturday morning technical session Dr. Paul A. McNally, of Georgetown University, Washington, D.C., showed a coloured moving picture of the National Geographic Society's eclipse expedition of October 1, 1940, to Patos, Brazil. He also showed slides which indicated that by silvering the front lens of one of their cameras they had found it possible to take photos of the sun through the silver film, so free from halation that the eclipse contact times could be determined to within half a second, as compared to two seconds' accuracy by previous methods. Mrs. Catherine Stillman

Pierce stated that the Massachusetts Institute of Technology radio eclipse expedition to South Africa had found that the upper Heaviside-Kennelly ionized layer practically disappeared during the period of totality, at its height above the ground, and that as various groups of sun-spots disappeared the ionization in the layer dropped abruptly.

Mr. Campbell, Pickering Memorial Astronomer at Harvard, asked the question, "Do ordinary novae repeat?" He showed a curve the ordinate of which was the number of magnitudes' increase in brightness of a star, and the abscissa of which was a logarithmic scale of the period between outbursts. Points were plotted on this for recurrent "cataclysmic" stars such as SS Cygni and U Geminorum, and the known repetitive novae such as RS Ophiuchi. These points fell on a smooth curve, with larger range of brightness corresponding to increased period, so that some credence may be given to the possibility that novae may repeat, though at very long intervals in the case of the brighter ones.

Miss Ida Barney of Yale described the new catalogue of star positions which she is drawing up, upon which astronomers of future generations can base more accurate estimates of the proper motions of the stars.

In the afternoon more mundane pursuits were followed and the members toured the Vanderbilt Mansion and Estate which overlooks the Hudson River and the Catskill Mountains. Two antique brass orreries were on display in the dining room of the mansion and autographed photographs of King Edward VII and the Duke and Duchess of Connaught, Governor-General of Canada during the first World War were standing on one of the tables in the drawing room.

At the Saturday night banquet Everett S. Rademacher, M.D., New Haven, Connecticut, spoke on the relationships between psychiatry and astronomy. Apparently many neurasthenics are of the impression that some astronomical body has a malign influence on them. One of Dr. Rademacher's patients felt that the changing phases of the moon induced periods of lethargy. Another felt herself to be under some evil influence supposed to be emanating from the sign or constellation Scorpio, while still other patients felt that the fall of meteors portended personal disasters.

Dr. Alice Farnsworth gave an illustrated talk on her trip around

South America last fall and of her studies of the spectrum of the night sky.

It was announced that, through the invitation of Dr. Harlow Shapley, the next meeting would be held on October 10 and 11 at Harvard Observatory.

REVIEW OF PUBLICATIONS

Barlow's Tables of squares, cubes, square roots, cube roots and reciprocals of all integer numbers up to 12,500. Fourth edition revised and enlarged by L. J. Comrie, M.A., Ph.D. 272 pages, 5¼ x 8¼ in. London, Spon, 1941. Price 8/6.

The first edition of *Barlow's Tables* appeared in 1814. A new edition was edited by De Morgan in 1840 and the stereo plates for it were used until 1930 when the whole work was revised by Dr. Comrie and re-set for a third edition. It is interesting to see a fourth edition called for after a period of eleven years. The work has been enlarged, the chief change being the extension of the numbers from 10,000 to 12,500. At the present time calculating machines are being adapted for all sorts of computations and the tables in this book are continually increasing in usefulness.

Peter Barlow of the Royal Military Academy, Woolwich, by whom the original tables were produced, devoted much time and labour in order that they should be free from error, remarks in language rather characteristic of the period: "being well aware that the utility of the performance depended wholly upon its accuracy, I have been the more cautious of guarding it from an imperfection which could not fail of depreciating value in the estimation of the public." Dr. Comrie has spared no effort to rid the tables of all errors and it will be interesting to see if the next decade will reveal any.

C. A. C.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

A New Calendar: When Shall We Have It?

In recent years two chief proposals have been made for improving our present inconvenient calendar. One was that there should be in each year thirteen months, each of twenty-eight days. This received considerable support and in the conduct of business it would have been very effective. But to adopt it would have demanded changes which seemed startling to the plain ordinary people and no general acceptance of it appeared possible. The other plan has been called The World Calendar. In it there are twelve months as at present, but the annoying features of the calendar now in use are eliminated. The days are so adjusted that the four quarters of the year are identical and every year has the same day of the week on the same date.

For some years this calendar has been ably advocated by The World Calendar Association, Inc., with office at 630 Fifth Avenue, New York, N.Y. Miss Elisabeth Achelis is its capable president. This organization is a non-profit, educational corporation and its sole object is advancing the cause of The World Calendar. It has issued an attractive 32-page booklet, which is distributed free and which presents in a clear and readable way the benefits to be derived from the new calendar. A suitable year to introduce it is 1945, and many hope that it may come into operation then. In the following quotation Miss Achelis makes an appeal for support for the new calendar.

> We in this association have one objective—to improve the calendar, to make it balanced, stable and equable. We confine ourselves to this goal. We do not claim that The World Calendar will solve the world's ills beyond those we have described in this booklet. But we do urge this particular time-plan because we believe it will benefit everybody. To delay its adoption any longer will retard the smooth progression of our days.
>
> Do you want to help? Then think over the proposal we have presented in this pamphlet, and if you find it logical, and sensible, as I think you will, then write about it, talk about it, and in your own field, ACT upon it. If you do not know where to begin—write to us, and we will assist you.
>
> To adopt the new calendar it would be highly desirable to have the general

consent of all the nations on earth. Calendar history, however, has shown us that this is not essential. Even to-day all the world does not reckon by one and the same calendar. Changes in the past have been of necessity religious or political. To-day the calendar stands free for everybody to voice his opinion of this suggested change. In The World Calendar, there exists no political bias, no special interest, no national prejudice.

We should be shortsighted indeed were we to fail to recognize that in that phrase, "the general consent of all the nations on earth" are implied world amity, the civilized recognition of man's common humanity and needs, and a sense of federation of nations in this new federation of time.

Here we envision the possibility of a greater gain to mankind than even that of The World Calendar. Here is the promise of helping toward a renascence of man's consciousness of the stake he has in the progress of civilization.

That is an ideal reflected in our calling The World Calendar—"A New Calendar, for a New World."

The 200-inch Telescope

The interest in this great instrument is very widespread and any authoritative information regarding progress on it is very welcome. At the meeting of the Pacific Division of the American Association for the Advancement of Science held at Pasadena, June 16-20, an address on the telescope was made by Dr. Max Mason, chairman of the Observatory Council. No full report is available and the information which follows is given by *Science Service*.

It is thirteen years since Dr. George E. Hale convinced the Rockefeller International Education Board of the feasibility of such an instrument and an appropriation of six million dollars was made to produce it. The disc for the mirror originally weighed 21 tons and in grinding it nearly four tons of glass have been removed. The front of the disc is solid but the back is ribbed, mainly to reduce its weight. By a system of 36 levers the mirror is held in the holes between the ribs.

"The supporting system must operate so perfectly that no bending of the reflecting surface beyond one or two millionths of an inch will occur as the telescope moves. As the surface of the mirror was brought by polishing close to a spherical form it became clear that the disc when tipped from the grinding table to a vertical position for optical test, sagged slightly under gravity. After

months of study, as the polishing continued, this sag was eliminated by installing a system of 24 'squeeze' levers, operated by counter weights, distributed around the rim of the glass."

After the spherical form has been reached the surface will be changed to a paraboloid by deepening the concavity slightly, the amount at the centre being five thousandths of an inch.

The mounting of the telescope on Mount Palomar is completed. Final adjustment of it must be made optically, and in the absence of the great mirror one twelve inches in diameter will be installed and the working of the mounting will be studied. Just when the instrument will be finally completed it is impossible to state but the difficulties which have been met have been overcome. When in operation it will probably not be used for photographing the moon or the planets but will be used to study faint and distant galaxies and to analyse in great detail the light received from the stars and planets. For this work several new auxiliary instruments are being constructed in the California Institute of Technology workshops.

Noise and Quiet

Recently a physicist having some long and tedious calculations to make sought the loan of a computing machine from an astronomical friend who is equally competent in the use of logarithms and computing machines.

Physicist: Which do you prefer in computing, logarithms or a computing machine?

Astronomer: Oh, I think I like logarithms, they are so quiet.

The present writer has recently returned from a few weeks at a summer cottage on the rocky shore of crystal-clear water in northern Ontario, and he thinks that in the case of motor boat (especially of the familiar outboard sort) and rowboat there is much to be said in favour of the latter,—it is so quiet!

C. A. C.

MEETINGS OF THE SOCIETY

AT VICTORIA

February 12, 1941.—The meeting was held in the Y.W.C.A. and was called to order at 8.05 p.m. by the president, Dr. R. M. Petrie.

Mr. F. R. Moore was elected a member of the Society.

Miss Hailstone acknowledged the gift of a number of pamphlets from Mr. Brydon and called attention to the new edition of "Our Wonderful Universe" by Dr. Chant.

The members were then given a special treat in the lecture on "Exceptions to the Rule" by Professor Walter Gage of the University of British Columbia. Professor Gage first stressed that applied mathematics had been of great importance in the development of astronomy, physics, radio, statistics, life insurance, etc., but such a résumé was not his purpose to-night. By quoting liberally from Lewis Carroll, he led the audience from one step to the next until they were hopelessly lost in the maze of mathematical peculiarities until they could say with Alice: "What is the best way out of this wood? It's getting so dark. Would you tell me please?"

In the fourth century B.C., Zeno proved, by means of his paradoxes of dichotomy, Achilles and the tortoise, the arrow, and the stadium, that motion is impossible according to either the discrete particle or continuous theory of matter—and even now the fallacies are difficult to explain. In a series of demonstrations that a part is equal to the whole, Professor Gage showed that, by using an infinite number and the word "all", any desired fact may be proved and, in conclusion, quoted Godel's 1931 statement that "it is impossible in any system of arithmetic to prove that you will not get a contradiction", and thus came back to Zeno's original argument that "space, time and motion as perceived by our senses are incompletely represented by the mathematical concepts bearing the same name".

March 5, 1941.—The President, Dr. R. M. Petrie, called the meeting to order at 8.10 p.m.

Mrs. E. M. Anderson and Messrs. Louis Bagnall and Graham L. Anderson, were elected members, the latter two as Junior Members.

The librarian, Miss Hailstone, reviewed "Great Men of Science" by Grove Wilson; current phenomena, which included a partial eclipse of the moon on March 13, were discussed by Dr. K. O. Wright; and it was announced that the six members of the telescope making section were meeting every Thursday. To complete the first portion of the meeting, a short talk on the Stars of the Southern Sky was given by Professor W. H. White of the University of London.

As speaker of the evening, the members were favoured by the presence of

Mr. Robert Peters, past president of the centre, who had chosen for his subject "A Master Astronomer". Sir Isaac Newton had one of the greatest mathematical minds of all time but spent comparatively little time on this subject. As a youth, farming was his first occupation, but his genius was soon recognized and he was sent to the University of Cambridge in 1660, where his master, Professor Barrow, fully appreciated the young man's talent and resigned his chair in Newton's favour eight years later. At the age of 23 Newton had invented his "method of fluxions", which is the differential calculus of to-day, and contributed to the theory of light and had studied it by means of a prism, and had solved the problem of gravitation in his own mind. His experiments on the nature of light and the theory of chromatic aberration were presented before the Royal Society but inconsequential controversies, particularly with Robert Hooke, led Newton to keep his studies to himself in future. It was only through the great efforts of Edmund Halley that the discoveries and results obtained from the law of gravitation were studied in detail but, by dint of his tremendous powers of concentration, "The Principia" was written and prepared for publication between December, 1684 and May, 1686. In preparing his book, Newton proved his theorems by means of his "fluxions" but as no one else could understand them, it was necessary to translate these methods into geometric form. Thus, at the age of 42, Newton had completed his most important work. He lived 43 years longer but spent most of his time experimenting in alchemy and studying theology and few tangible results were obtained. Newton's mathematical powers remained, however, for fifteen years later he solved Bernoulli's problems in a single evening, though other mathematicians had been working vainly at them for more than a year.

After this analysis of Newton's life, Commander Tingley gave a demonstration of the sextant, which had been improved by Newton, and a number of questions were asked by members of the audience. The meeting adjourned at 9.50 p.m.

March 26, 1941.—At 8.10 p.m. the President, Dr. R. M. Petrie, called the meeting to order.

The following were elected to membership in the Society: Constable R. J. Meek and George R. T. Freeman.

The librarian, Miss Hailstone, reviewed the *Radio Talks* of W. E. Harper, a book which had recently been bound for the library, and Dr. Wright discussed the current phenomena of the next three weeks. Captain Everall then took the chair and called on the President to address the Society on "The Structure and Dimensions of our Universe".

Dr. Petrie stressed that a relatively small portion of our universe is visible to us and gave a short preview of the subject by showing a series of slides of the galaxy as seen by a person far out in space who gradually approached the earth. But to astronomers on the earth, stars appear in all directions and the difficulties in obtaining a clear view of the whole system are immense. Wright and Lambert made excellent guesses concerning its shape with very limited

data; Herschel obtained accurate observations with his star gauges and was able to show that the galaxy is similar to a watch-shaped disc. Modern star counts include fainter stars but confirm Herschel's general conclusions with the addition of a local system of stars which may be similar to a knot in a spiral nebula.

The motions of the galaxy were then considered and it was mentioned that Sir John Herschel first suggested that the spheroidal form of the galaxy might be due to rotation. In 1912 Turner noted certain peculiarities in the motions of the stars and in 1925, Oort attempted to form a model of the galaxy on the basis of its rotation. Since then, Plaskett and Pearce have shown, from analyses of both proper motions and radial velocities of the stars, that the galaxy does rotate and the period of rotation at the sun is 224,000,000 years. Finally the speaker compared pictures of the Milky Way with those of the Andromeda and other spiral nebulae and noted the great resemblances in many important details.

April 16, 1941.—At 8.10 p.m. the President, Dr. R. M. Petrie, called the meeting to order. Miss Hailstone, the librarian, gave a brief review of "The Expanding Universe" by Sir Arthur Eddington, and Mr. Shaw gave a report from the telescope-making section which noted good progress on their mirrors by eight enthusiasts. Mr. Peters then presented a short description of the aspect of the heavens in which he stressed that the earth had made a quarter of its yearly revolution about the sun and now Leo, with Regulus, was almost overhead and Boötes, with Arcturus, could be seen in the east at the beginning of the evening. The president announced that the Summer Course would be held as usual during July and August and that members would be notified about these meetings in due course.

The main address of the evening was given by Dr. K. O. Wright who had chosen the topic "How Hot Are the Stars?" The methods of determining temperature by means of the laws of radiation of Stefan, Wien and Planck were first discussed and it was shown how the spectral-energy curve varied with temperature. The pyrheliometers, new and old, which are used to measure the heat received from the sun, were studied and also the vacuum thermocouples of Coblentz and Pettit and Nicholson, as these are the only direct methods of determining the amount of heat received from the stars. A brief description of the classification of spectra showed how temperature and spectral type are related and then the methods of determining the colour, effective and excitation temperatures of the stars were summarized. Finally a comparison of the various temperature scales by Brill and Kuiper showed that there are still certain discrepancies and further work is required in this part of the field of astrophysics.

KENNETH O. WRIGHT, *Recorder.*

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1890-1941

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For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal, P.Q.; Ottawa, Toronto, Hamilton and London, Ontario.; Winnipeg, Man.; Edmonton, Alta.; Vancouver and Victoria, B.C. As well as about 700 members of these Canadian Centres, there are over 200 members not attached to any Centre, mostly resident in other nations, while some 300 additional institutions or persons are on the regular mailing list for our publications.

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